Landslides on Logged Areas in Southeast Alaska

by
Daniel M. Bishop
and
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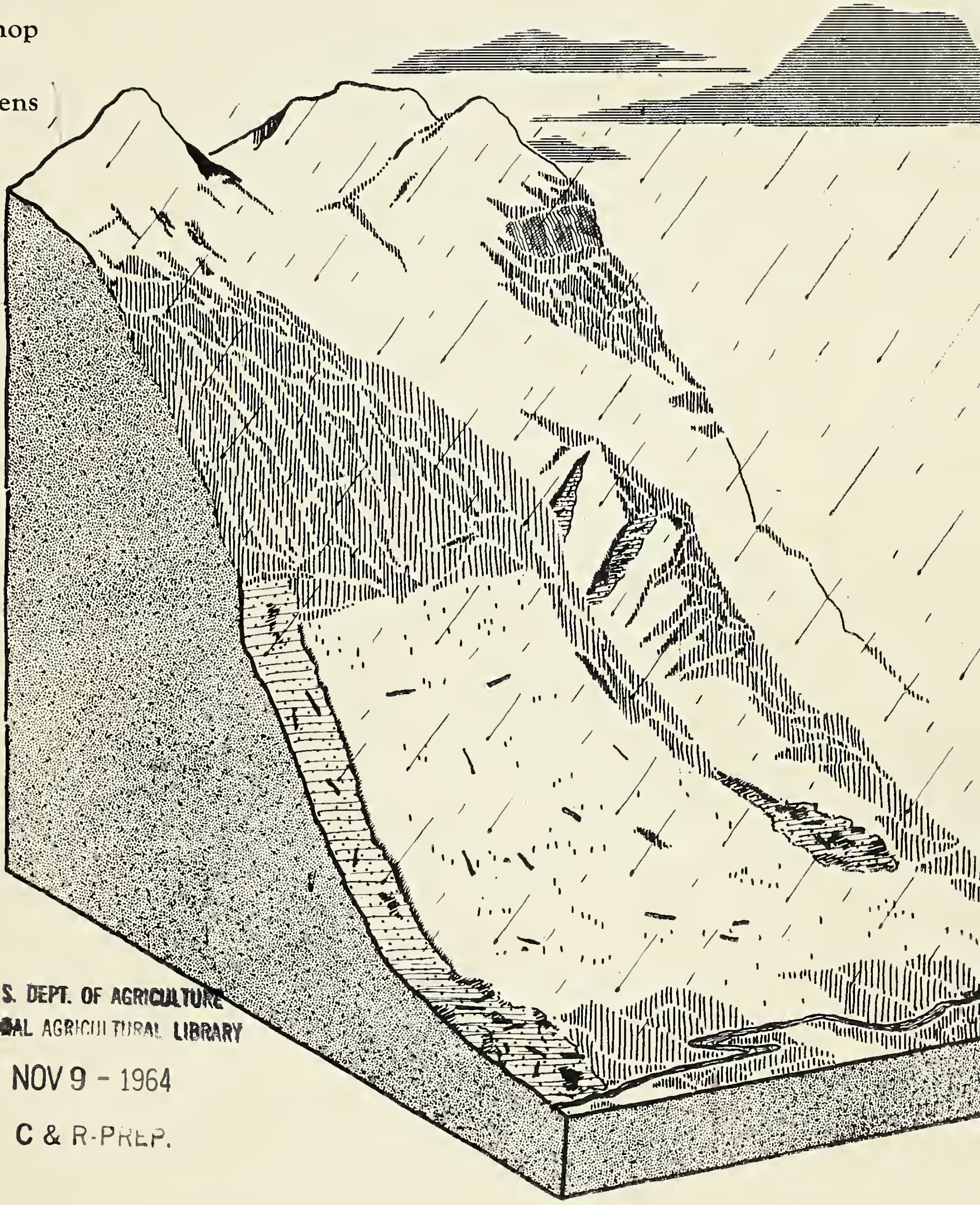

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Logged areas in Maybeso Creek valley. The topography is typical of many valleys seen in southeast Alaska.

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INTRODUCTION

This reconnaissance was prompted by mass soil movements that occurred in October 1961 in several areas recently logged by a high-lead system. Slides and torrent flows were especially numerous in the Maybeso Creek valley (45 miles west of Ketchikan) and the Neets Bay-Gedney Pass area (30 miles northeast of Ketchikan) as shown in figure 1.

A decade ago erosion was not considered a serious problem in southeast Alaska. Past logging operations were concentrated mainly in the better timber stands along beaches and in valley

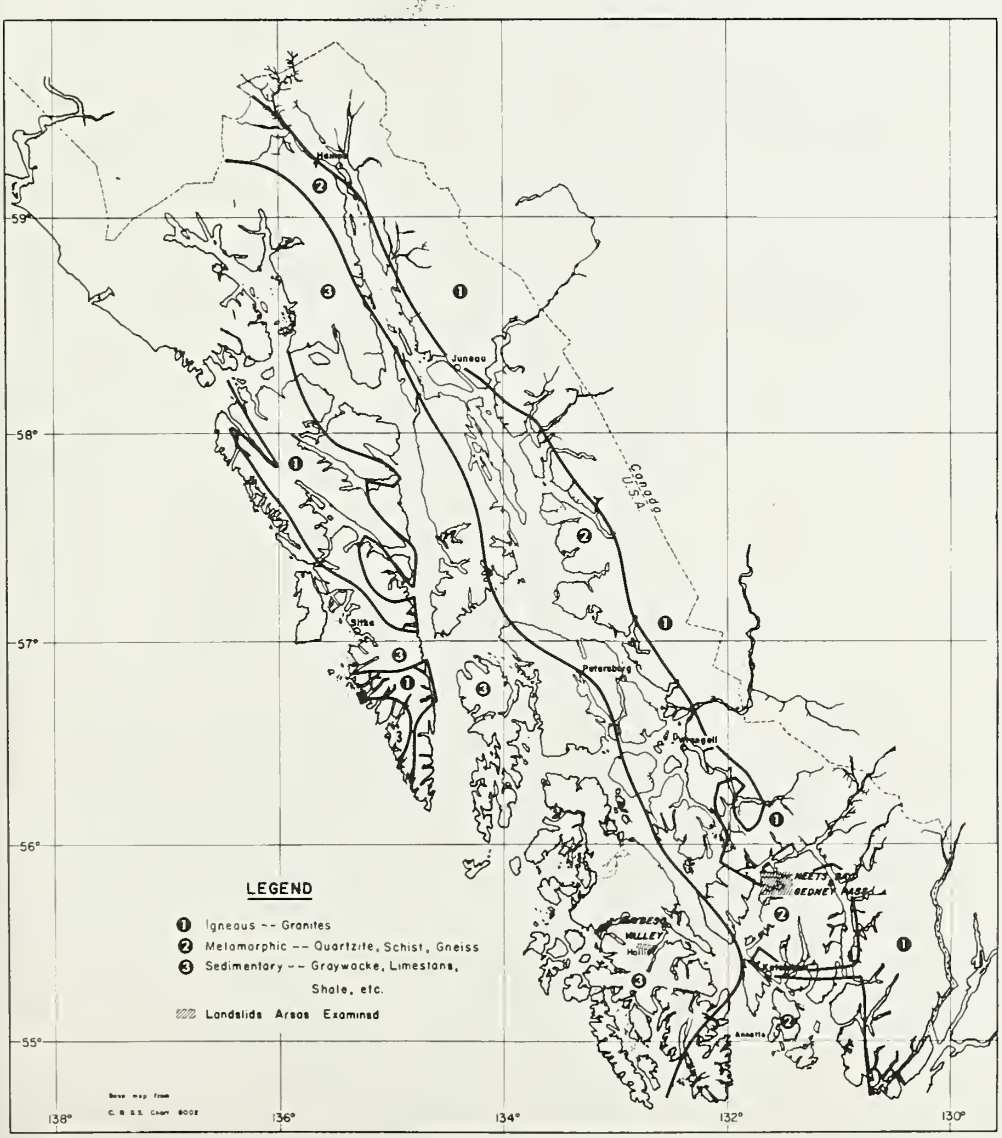

Figure 1.—Generalized bedrock geology of southeast Alaska. Adapted from Geologic Map of Alaska (Dutro and Payne, 1954).

bottoms. Large-scale clear cutting that began in the mid-1950's was the first to include steeper slopes. Areas having a high erosion hazard are now being logged. One apparent consequence of large-scale logging is an increase in soil movement.

LITERATURE REVIEW

While many studies have been made on landslide phenomena, those regarding such activity in timbered areas are of special interest. These include studies of landslides in New Hampshire, Utah, and Oregon as well as Japan and Italy.

In New England, Flaccus (1959) prepared a doctoral dissertation on landslides and their revegetation in the White Mountains of New Hampshire. His work is significant for our study because the White Mountains are of recent glacial vintage. Soil mantles of glacial till are found in southeast Alaska. In the White Mountains, slides also generally occur during the fall rainy season as is true in southeast Alaska. But there are also important differences:

1. Southeast Alaska has more rainfall.

2. The White Mountains have a much greater rainfall intensity, according to Yarnell (1935) and U. S. Weather Bureau records for the Annette Island, Alaska, station.

3. The White Mountains have greater extremes in temperature; colder winters and warmer summers.

Flaccus (1959, pp. 88-89) summarizes the complex factors that contribute to landslides in the White Mountains.

> Conditions of instability have been produced by glacial, stream erosional, and mass wastage phenomena. Physical factors of the bedrock, such as sheet-jointing parallel to slope, are important, especially in the case of ledge slides in areas of plutonic rocks, but are not necessary for slide occurrence. Degree of slope is of obvious importance. Given slide-susceptible slopes, the universal and most important single causative factor is heavy rainfall during those months free of ground frost. Most slides are associated with high-intensity rainfall, but fixing of intensities required is difficult.
>
> While effects of forest cover cannot be ruled out, evidence suggests that lumbering has had no part in contributing to slide occurrence. Conversely, there are at least theoretical reasons for suspecting that forest maturity tends to increase, to a minor degree, slide probability.

Another area of difficulty with landslides in timbered areas has been the Wasatch Mountains of Utah. Croft and Adams (1950) concluded that before modern-day land use "landslides . . . were . . . rare, if not entirely absent, in this drainage basin since the present mineral mantle developed on its slopes." They attribute the recent occurrences of landslides largely to loss of mechanical support by root systems of

trees and plants, chiefly by timber cutting and burning and, to some extent, by excessive livestock grazing. In line with these observations, they concluded further that "young second-growth timber...falls far short of providing the root support that its much larger and older predecessors did."

Fredriksen (1963) reported on a recent mud-rock slide in a timbered experimental watershed near Blue River, Oregon. Although there was ample evidence of old slides on the timbered slopes of this area, Fredriksen concluded:

> In spite of precautions taken in road location and construction, it appears that the presence of the road and culvert triggered this mass soil movement. Even a "full benched" road inevitably upsets the balance of forces with the soil mantle. A decision to build a road in an area of unstable topography constitutes a calculated risk no matter how well the road is designed and constructed to minimize damage.

Reporting on investigations made of slides occurring in 1954 on Shikoku Island, Japan, Kawaguchi and Namba (1956) place great value on a well-rooted forest cover. They believe a root mat strengthens the surface soil, while tree stems act to arrest rolling stones.

Ohhira and Nakamura (1956) examined "characteristics of landslide movement and landslide soils" in one general area on Shikoku Island and two general areas on Honshu Island, Japan. According to the English resume, these slides or flows were highly variable in speed and recurred repeatedly in an area. Soils in such areas were high in plasticity with clay minerals variable and montmorillonite usually dominant.

Kawaguchi et al. (1959) examined landslides and soil losses that occurred in 1958 in an area southwest of Tokyo, Japan. Landslides fed greatly swollen streams which deposited rocks, soil, and other debris on cultivated and residential land. They reported:

> Most of the landslides happened in the young forest-stands, shrublands, and grasslands. The degree of landslides in the National Forest having good forests is lower than that in the private and communal forest, and the preventive function of the forest against landslides increases with increase of its age class. But the types of landslides beyond the preventive function of the forest also occurred.

These authors doubt that it is possible to effectively predict location of slides. They do, however, recommend a number of specific preventative practices:

1. Vegetate -- deep-rooted trees are especially effective for retarding slides of the "surface-sliding type."
2. Build check dams, revetments, and spurs to retard or resist torrents.
3. Provide underground drainage to prevent sliding in some cases.
4. Protect homes and buildings from slides by man-made barriers and by forest stands.

5. Locate roads and trails in valley bottoms.

Landslides are familiar in Italy; Leonardo da Vinci spoke of them in his time. Although Italy does not have the great rains of Japan there is a general similarity between landslides in the two countries. Rehabilitation is also similar. Bernardini (1957) sums up landslides near the plains of Lombardy as

> ...very ancient phenomenons [sic]...showing...a form of slide caused by water infiltration in Eocenic clay and marl soils. The technichs [sic] of control is based on the elimination of this principal factor and on the soil conservation measures, completed by the vegetation cover and chiefly by the afforestation.

In a general paper on Italian landslides -- their causes, classification, prevention, restoration -- Cappuccini and Bernardini (1957) state (as translated locally), "An insufficient vegetation is particularly important in the formation of landslides; this last circumstance constitutes the most important cause of landslides."

SHEAR STRESS AND SHEAR STRENGTH

It is essential that major causes of landslides in southeast Alaska be examined in terms of shear stress and shear strength.[1] Soil technologists emphasize that an understanding of these factors is fundamental yet difficult in pinpointing causes for specific slides, as Sowers and Sowers (1951, p. 228) point out:

> In most cases, a number of causes (for landslides or flows) exist simultaneously, and so attempting to decide which one finally produced failure is not only difficult but also incorrect. Often the final factor is nothing more than a trigger that set in motion an earth mass that was already on the verge of failure.

Varnes (Highway Research Board, 1958, Chapter 3) outlined contributory processes of landslides in terms of shear stress and shear strength. This method was used to examine factors causing landslides in southeast Alaska.

Factors Influencing Shear Stress

Glaciation.--Glaciation is evident throughout the area. During the latest glacial period, valley glaciers carved steep U-shaped valleys. Erosion has not acted long enough to moderate the glacial slopes to more stable forms. Consequently, the soils on which many logging operations are conducted are derived from glacial deposits laid down on very steep or oversteepened slopes. (Oversteepened slopes are viewed as unstable slopes or slopes beyond their angle of repose.) Glacially steepened slopes are shown in figures 2, 3, and 4.

Earthquakes.--Earthquakes are not uncommon in some parts of southeast

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1/ Stress--a strain resulting from applied forces that cause or tend to cause contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact. Strength-capacity of a material to resist shear.

Figure 2.—View down the glaciated valley of Maybeso Creek, Hollis, Alaska. Smooth south-facing slopes are shown on the left and broken topography on the right.

Figure 3.—Smooth granite walls in Rudyerd Bay, Behm Canal, are striking examples of steep glacial topography.

Figure 4.—Glaciated Neets Creek valley, Alaska, where weak metamorphic formations have released large rock masses into the valley bottom (arrow 1). Mass wasting of soil and rock also produced the fan below the ravine (arrow 2).

Alaska. The Yakutat-Lituya Bay region is an example of known faulting and earthquake generation. Quakes may trigger unstable slopes to move. Although earthquakes were observed in Alaska during October 1961, none were recorded for the Ketchikan area during the first part of October [2/].

Tilting.--Faulting or uplifting can tilt the earth's surface, contributing to formation of oversteepened slopes. Near Yakutat, for example, one faulting action in September 1899 raised the coastline near Hubbard Glacier 47 feet (Tarr and Martin 1912, p. 15). Uplifting seems to be an isostatic response to the great loss of ice weight following recent glaciation (Flint 1957) and has been observed by the U. S. Coast and Geodetic Survey at many tide stations in southeast Alaska lying north of latitude 58°N. Uplift rates range from 0.01 feet per year to 0.13 feet per year (Shofnos 1961).

Faulting or uplifting may steepen stream gradients. Tributary torrent streams may then produce and maintain oversteepened ravine slopes.

Precipitation.--Annual precipitation ranges from 45 inches at Angoon (Admiralty Island) to 217 inches at Little Port Walter (southern end of Baranof Island) [3/]. The average precipitation, however, is about 100 inches. Heavy rains develop shear stresses within the soil profile by adding the weight or driving force of water to the soil mantle and vegetation.

Vegetation.--Vegetation below timberline is mainly western hemlock (Tsuga heterophylla (Raf.) Sarg.)-Sitka spruce (Picea sitchensis (Bong.) Carr.) forest interspersed with occasional muskegs. The weight of timber itself is a significant part of the shearing force in the soil mantle.

2/ Personal correspondence with Merril C. Cleven, Geophysicist, U. S. Coast and Geodetic Survey, May 24, 1962.

3/ U. S. Weather Bureau, Dept. of Commerce, Climatological Data, Alaska, 1961, and from records of the Cooperative Weather Station at Hollis maintained by the Northern Forest Experiment Station.

Construction.--Road building can increase shear stress by filling or side-casting on slopes.

Factors Influencing Shear Strength

Parent materials.--The initial composition and structure of parent material plays an important role in shear strength. Figure 1 shows the variety of parent rock in southeast Alaska.

Glacier-worn granitic slopes frequently offer little support for soil or vegetation. Examples of areas with such slopes are found along the mainland granitic mass, particularly in the Behm Canal area (fig. 3).

Weak geologic structure is evident in some locales. In the valley east of Neets Bay, land forms show geologically recent failures in metamorphic materials (fig. 4). This activity is associated with uplifting and intrusive forces acting upon antecedent formations. Hence, failures might be expected along contacts between igneous and metamorphic masses.

Bedding structure is a critical factor in some locales. This is frequently found in the metamorphosed areas shown in figure 1. An example (fig. 5) is Neets Bay.

Compacted glacial tills that act as a slide plane when wet were found in the Maybeso Creek valley and in Neets Bay-Gedney Pass. There may be, in southeast Alaska, glacial tills in a wetted state or tills having rougher interfaces with the overlying soils that are not as susceptible to sliding.

Some metamorphics, such as schists and gneisses, produce inherently weak soils that are high in micas. An example is the Neets Bay area. Fracturing and weathering characteristics of rock also may produce a weak foundation for the soil mantle. Some areas with diorite rock have weathered sufficiently to produce a thin mantle of small angular blocks overlying the unweathered surface. Soil filtering into these fissures gradually forces these blocks apart by freezing and thawing. This action, combined with gravity acting on steep slopes, produces a soil mantle weak in shear strength. Granites that disintegrate into soils that are high in sand content and low in shear strength occur on the mainland and parts of some islands in southeast Alaska.

Pore water.--Pore water within the soil can act to reduce shear strength. Varnes (Highway Research Board, 1958, Chapt. 3, p. 45) lists the following

Figure 5.—The effect of bedding is shown in this ravine through metamorphics. Parallel-bedded slope is bare; opposite slope retains soil mantle. Neets Bay, Alaska.

three ways in which pore water may reduce shear strength:

1. "Buoyancy in saturated state decreases effective intergranular pressure and friction." In the case of soils that slide on glacial till, the horizons above the compacted till have a much lower bulk density than the till itself. The till is also nearly impermeable while the overlying soil is not. Thus, the soil, when saturated, has a tendency to "float" on the till.
2. "Intergranular pressure due to capillary tension in moist soil is destroyed upon saturation." Most soils subject to sliding appear to be below field capacity before the fall rainy season. These shallow soils, however, can quickly approach maximum water-holding capacity. No intergranular pressure exists at saturation moisture levels.
3. "Seepage pressures of percolating ground water result from viscous drag between liquid and solid grains."

In cohesionless soils[4/], significant pore pressures usually are not developed. Sandy loam soils of the Maybeso Creek valley probably conform to the cohesionless definition. The similarity of Maybeso Creek valley soils to other southeast Alaska soils leads us to suppose that cohesionless soils are widespread.

Compacted cohesionless soil tends to increase in volume as it shears. Such a volume increase is opposed by a saturated but draining condition. Hence a resistance to shear is developed.

Despite a complex and variable relation with soil water, cohesive soils are easier to generalize upon because they consistently lose shear strength with addition of water.

Weight.--Timber removed from a cohesionless soil will cause a reduction in shear strength in proportion to the change in weight because there is a change in force normal to the slide plane. This strength loss, however, is balanced by an equal stress reduction[5/]. Coulomb's formula, shear strength = (coef. friction) x (net force normal to slide plane), expresses this relation for cohesionless soil.

Root deterioration.--Gradual deterioration of the root network follows the timber harvest. The tenacious hold of root hairs and fine roots to soil particles is gradually lost. Loss of continuity in the network of tree roots near the soil surface may weaken the soil mantle. With a discontinuous root network on the slopes, strong anchor points that resist shear cannot absorb additional shear stress from weakened adjoining areas.

Construction.--Construction affects shear strength as well as shear stress. Road construction may reduce shear strength by undermining support for the upslope soil mantle.

4/ Hough (1957, p. 139) describes cohesionless soils as being predominantly of silt, sand, and gravel-size fractions. "Individual particles...are of such size as to be influenced primarily by gravitational forces and forces due to seepage and boundary loading rather than colloidal forces."

5/ Stress-strength balancing with weight change should also be true for water-content changes in cohesionless soil.

Table 1.--Acreage and number of slides by periods between aerial photography in the Maybeso Creek valley, Hollis, Alaska

When photos were taken		Time period	Area affected: For time period	Area affected: Cumulative total	Number of slides: On uniform slopes 1/	Number of slides: In concentrated drainages 2/	Number of slides: Total for time period
		Years	Acres	Acres			
				BEFORE LOGGING			
June	1948	approx. 100	27.3	--	2	10	12
July	1952	4	4.2	31.5	0	1	1
				DURING AND AFTER LOGGING 3/			
May	1959	7	6.2	37.7	2	18	20
May	1961	2	21.6	59.3	2	26	28
August	1962	1	90.8	150.1	16	52	68

1/ These slides occurred on the smooth, flat slopes between major side drainageways.
2/ These slides occurred within concentrated (V-shaped) drainages.
3/ Logging began in 1953.

RESULTS AND DISCUSSION

A reconnaissance of the Maybeso Creek valley and Neets Bay-Gedney Pass areas was made in 1961 and 1962 to gain a better understanding of the significance and possible causes of the landslides that occurred in these areas in 1961. Recurring aerial photo coverage provided a means for estimating previous as well as recent landslide occurrence (table 1).

Of the 12 slides in the Maybeso Creek valley before 1948, one occurred on the north-facing slope, probably about 36 years ago. The other 11 apparently occurred over 100 years ago. This is geologic erosion uninfluenced by man. The older slide areas supported merchantable timber and were logged.

There was a drastic change in the landslide pattern for this area after logging began in 1953 (fig. 6). The number and acreage of slides since 1953 increased four and one-half or more times. It shouldn't be overlooked, either, that these increases occurred in a period of less than 10 years.

Figure 6.—October 1961 debris avalanches and flows in the mile-square clearcutting in the Maybeso Creek drainage, Hollis, Alaska. The Karta soil series is between the dashed lines. Photo taken August 8, 1962.

Figure 7.—The starting zone of a mile-long slide in uncut timber. Neets Bay, Alaska.

Slides in the Neets Bay area may also have increased in frequency after logging. Aerial photos taken in 1948 do not show evidence of slides in the commercial timber areas that were subsequently logged. Two slides that occurred in recent decades were seen at the mouth of the bay. In the area observed in the field, at least a half-dozen slides found on steep logged areas extended to the beach. Numerous small soil slips were also evident throughout the area. A mile-long slide had occurred in a ravine within uncut timber (fig. 7). Another smaller slide within the timber was reported but not visited. The scarcity of flows on timbered slopes near logged areas strongly indicates an increase in susceptibility to slides as a result of logging.

Effects of rainfall. -- The October 1961 landslide period was a time of unusually heavy rainfall (table 2). The normal precipitation pattern for this area is an increase from a relatively dry July to a maximum monthly rainfall in October.

In 1961, the heavy rainfall started in the later part of September and continued throughout October: For October the Hollis weather station recorded 9.95 inches more than normal; Ketchikan was 13.17 inches over the normal.

Table 2.--Precipitation at the Hollis and Ketchikan weather stations, July through November 1961, and the deviation from averages

Month	Hollis: Amount recorded	Hollis: Deviation from 6-year average	Ketchikan: Amount recorded	Ketchikan: Deviation from 49-year average
	Inches	Inches	Inches	Inches
July	2.67	-1.12	5.84	- 2.23
August	5.32	+0.39	17.12	+ 7.22
September	8.65	+0.80	10.42	- 4.27
October	32.26	+9.95	34.64	+13.17
November	13.57	+1.02	16.74	- 0.72

Rain gauge charts from this station show that 11.18 inches of rain fell from 5 p.m. September 29 to 5 p.m. October 5. Although rain continued to fall, the next high period was from 5 p.m. October 12 to 5 p.m. October 14, when 6.41 inches fell. During this last period, 5.0 inches of rain fell in one 24-hour period 6/.

Heavy rainfall similar to the October 1961 storm doubtless has occurred in years past. The slide recorded on the July 1952 photographs is believed to have occurred October 13, 1949 during a period of high rainfall.

Based on records since 1953, the heaviest rainfall for one observation day at Hollis occurred either on December 4 or 5, 1959 during a period of slide activity or on October 14, 1961. The heaviest 2-day rainfall (nearly 7 inches) was on December 4-5, 1959. The second greatest 2-day rainfall was on October 13-14, 1961. The third greatest 2-day rain was during the October 2-3, 1961 storm. Rainfall is one of the most apparent triggering forces causing slides in southeast Alaska.

Possible flow mechanics.--To this point, the terms slide or landslide have been used in a general and descriptive sense. Virtually all soil mass movements observed in southeast Alaska should be classified as debris avalanches or debris flows, using the system adopted by the Highway Research Board (1958). In many cases, a mass movement appears to begin as a debris avalanche, then shift, seemingly instantaneously, to a debris flow. This occurs frequently in drainageways, causing torrent conditions. This classification, a modification of Sharpe's system (1938, 1960), will be used hereafter.

Flow frequency can be related to topography--deeply entrenched drainageways versus smooth, uniform slopes. The south-facing slopes of Maybeso Creek valley are relatively smooth with long slopes extending without interruption from the ridge to the valley floor (fig. 2). Occasional mountain streams break the uniformity of the slope with deep, steep-sided ravines or canyons. It is apparent that the steep drainages (V-notches) are most susceptible to soil movement.

Logging on ravine walls tends to produce debris accumulations in ravine bottoms (fig. 8). A great increase in erosive power occurs (fig. 9) when this debris is brought into suspension by earthflows in the ravine. Such action was observed--and photographed while

Figure 8.—Logging debris accumulated in ravine bottom.

6/ U.S. Dept. Commerce, Weather Bureau Tech. Paper No. 47, 1963, indicates about a 10-year recurrence interval for this amount of 24-hour rainfall at Hollis.

Figure 9.—A debris avalanche-flow showing compacted glacial till (the lighter tone area in the gorge bottom).

in motion--during the October 5, 1961 storm. This opportunity came 5 minutes after one of the authors had climbed out of the gorge 75 to 100 feet downslope from the earthflow area (fig. 10). Erosion within steep tributary drainages assists in maintaining oversteepened slopes (fig. 11). The high slope angles produce high shear stress and unstable conditions are maintained until control is established naturally or artificially.

While ravines and canyons on the Maybeso Creek valley's south-facing slope were more susceptible to debris avalanche-flows than were adjacent relatively smooth slopes, the latter areas were much more prone to soil movement than ravines and canyons on the north-facing slope.

Several factors may combine to produce this difference. The south-facing slopes are relatively smooth and concave from the ridge to the valley bottom, while the north-facing slopes are broken up with benches, spurs, and massive rock formations. The south-facing slopes drain from the alpine ridge across shallow soils on very steep slopes directly to the deeper Karta soils which extend up to about 1,200 feet elevation. Little water is stored in ponds or muskegs along this route. In contrast, the north-facing slopes have two small lakes as well as rather large areas of flat muskeg benches. This condition, along with the broken nature of the slopes, may prevent steep lower slopes from being exposed to excessive volumes of water.

Difference in logging practices on smooth and broken slopes might also help to explain avalanche-flow frequencies. The uniform slopes are more easily logged and hence tend to have

Figure 10.—Gorge from which one of the authors climbed a few minutes before it began to flow.

Figure 11.—Erosion within tributary drainages assists in maintaining oversteepened slopes.

Figure 12.—Profiles of 15 landslides in Maybeso and Neets Bay-Gedney Pass areas showing maximum and minimum angles of slope release.

larger clearcuts, which extend higher on the slopes.

Form of slide profiles is concave for logged areas of the Maybeso Creek valley and Neets Bay-Gedney Pass (fig. 12). Field examination indicated that the initial zone of shear failure generally occurred at the head of flows. Upon this premise, slope angles of shear failure zones become significant. The slope angles for 15 flows on logged slopes are:

31°	37°	41°	45°
32°	38°	43°	46°
33°	39°	43°	46°
36°	39°	43°	

These values give some idea of the limits of stable, high-lead logged slopes in southeast Alaska. The mean slope angle was 39°28', or 82 percent, with a standard deviation of ± 5°.

The flows that were examined generally occurred on either smooth compacted soil horizon, parallel-bedded rock, or slopes where bedrock had been smoothed during glaciation. An example of a debris flow on parallel-bedded rock is shown in figure 13. Such slide planes are also found in glacial till soils (fig. 14). When any one of the above conditions occurs on steep slopes within heavy rainfall areas they are considered potential slide slopes.

Figure 13.—An example of the head of a debris flow on parallel bedded rock.

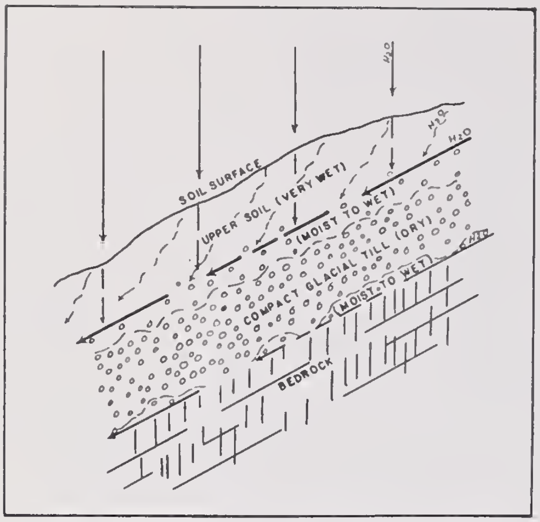

Figure 14.—Karta soil profile. The compact glacial till surface is the slide plane.

Compounding the issue is the inherent composition of weathered or transported material. Southeast Alaska has a wide range of rock and parent material types. Solution of future landslide problems will require knowledge of a diversity of parent materials. Knowledge of till composition will probably be needed to rate the risk of shearing. Similarly, an understanding of the composition of various exfoliating rocks will also be needed to interpret the slide potential of their weathered products. An example of this is found in Neets Bay where the parent materials (serecite schist, hornblende schist, amphibolite, quartz diorite, and gneiss) contributed to producing a flow-prone soil mantle. Another example occurs on the east side of Behm Canal. Granitic soils there are likely to be loose and noncohesive, which is a cause for slides in this area.

Well-drained Podzol soils of the Karta series occupy most of the slide areas of the Maybeso Creek valley. These soils develop from glacial till and from colluvial material of varied parentage (gray-wacke, silicified tuffs and shales, and occasional conglomerates). Gregory's[7/] analysis (table 3) leads us to consider this soil largely noncohesive. Little organic matter is incorporated with the mineral soil.

Work in other regions indicates that rate of water infiltration into forest soils is generally reduced by logging. It is also reasonable to presume that water-holding capacity does not increase with logging. Loss of organic matter and compaction of surface soil would oppose this. Thus the increase in soil shearing stresses produced by heavy rainfall should not be greater after logging; a relatively smaller stress increase is more to be expected.

Similarly, logging acts to reduce shear stress from timber weight. An approximation of how shearing force may change with clear cutting on landslide areas of Maybeso Creek valley is shown in figure 15. Reduced shear stress from such weight removal in cohesionless soils is balanced by an equal reduction in shear strength, as was pointed out earlier. As long as pore pressure cannot develop within the saturated cohesionless soils, weight and stress changes in or upon the soil do not alter the risk of shearing.

Another possibility for loss of shear strength is that the soil is locally compacted under the load of trees, thereby increasing shear strength. Logging -- and local unloading -- may cause "decompaction" by shrinking and swelling with soil moisture variation causing lowered shear strength.

7/ Gregory, Robert A. Progress report. Great soil groups of Maybeso Experimental Forest. 1955. (Unpublished report on file at North. Forest Expt. Sta., U.S. Forest Serv., Juneau, Alaska)

Table 3.--Particle sizes and organic material analyses of two soil profiles in glacial till, Maybeso Creek valley, Hollis, Alaska

Depth	Mechanical analysis: Sand	Mechanical analysis: Silt	Mechanical analysis: Clay	Organic material
Inches	Percent	Percent	Percent	Percent
		From about 300' elevation		
0-1/2	27.7	61.4	10.9	11.4
1/2-2	32.2	48.9	19.0	10.6
2-14	46.4	37.7	15.9	8.9
14-26	68.0	23.8	8.2	5.2
26-38	81.6	13.8	4.6	1.7
		From about 700' elevation		
0-1/2	30.8	59.3	9.9	2.8
1/2-16	53.0	39.1	7.9	6.0
16-27	56.5	39.1	4.4	5.9
27+	39.2	44.8	16.0	1.6

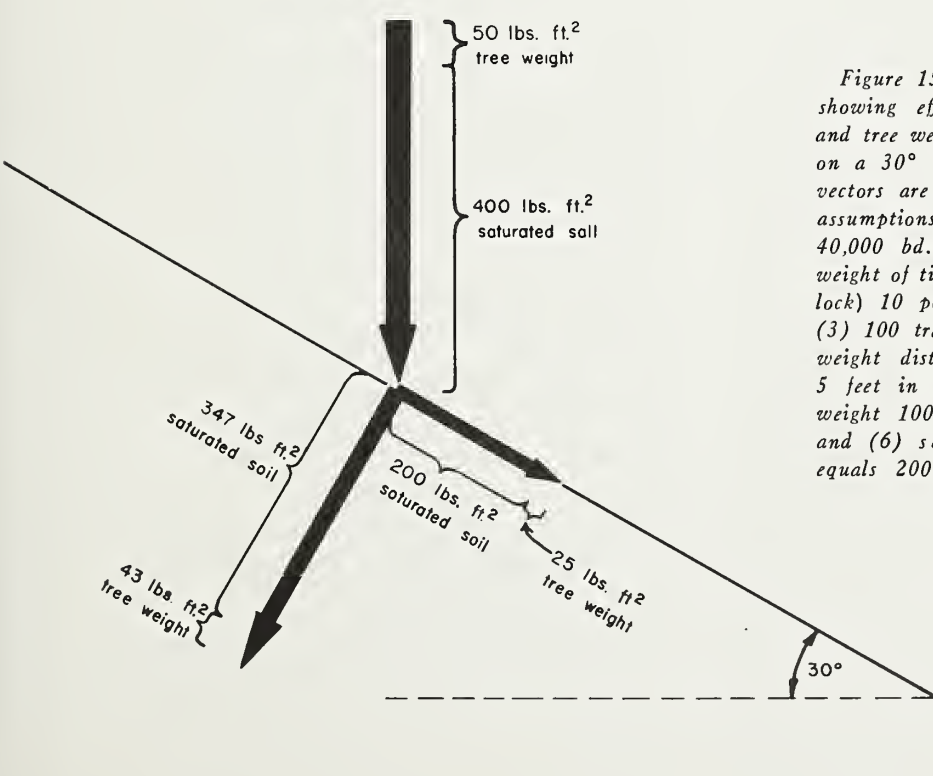

Figure 15.—Vector diagram showing effect of saturated soil and tree weights on shearing force on a 30° slope. These weight vectors are based upon following assumptions: (1) gross volume 40,000 bd. ft. per acre; (2) weight of timber (spruce and hemlock) 10 pounds per board feet; (3) 100 trees per acre; (4) tree weight distributed over an area 5 feet in radius; (5) dry soil weight 100 lbs. per cubic foot; and (6) saturated soil weight equals 200 lbs. per cubic foot.

Compaction, of course, is a commonly used technique for strengthening a body of soil. It is assumed compaction may occur under tree root systems. Whether this compacted region "decompacts" itself for a period after timber harvest is also hypothetical. If it does, it may decrease shear strength.

Road construction caused slope failure at several locations. Construction was through colluvial or glacial till deposits on slopes with high cut banks. On one occasion the failure was caused by an oversteepened roadcut slope. In this case the depth of uniform material was sufficient to cause a small rotational debris slide (fig. 16).

There is an apparent lag between date of cutting and date of flow occurrence. The possibility that this is an important factor in slide generation is suggested by the fact that few slides occurred during the rains of December 1959. These rains were heavier than the rains associated with the many slides of October 1961. This may reflect root deterioration time. When roots cease to function and start to decay, they offer more channels for water movement. It may be several years before the decay factor reaches its full impact on the total environmental system.

Figure 16.—Small landslip caused by road construction. Debris in foreground is lying on the road. Cut banks were about 6 or 7 feet high.

CONCLUSION

Recent large-scale clearcut logging of timber in southeast Alaska has accelerated debris avalanches and flows on steep slopes during heavy rainfall. Characteristics and possible mechanisms for these disturbances include:

1. Flows are more frequent within the V-notch side-drainages than on the smoother glacial valley walls. This may be attributed to V-notch channel downcutting producing oversteepened slopes.

2. Flows or avalanches usually slide on relatively smooth, wet planes oriented parallel to the slope when this plane is composed of such materials as glacial till, iron-organic layered material, metamorphosed sediments, or diorite. Such planes are resistant to downward water passage; hence, moisture builds up immediately above this layer.

3. Limited evidence leads to the assumption that southeast Alaskan flow-prone soils are usually cohesionless. If this is true, then soil pore pressure phenomena may not reasonably be expected.

4. A greater addition of water weight to the soil mantle through rainfall is not a likely stimulus for increased flows after logging. Research in other areas indicates

that water infiltration rate into the soil is reduced by clear-cut logging, and that loss of soil organic matter as a result of logging reduces water-holding capacity. If these findings are applicable to southeast Alaska, then less weight from soil water might be expected.

5. Weight loss by timber removal probably has no direct net effect on the likelihood of shearing since decrease of shear stress with unloading is equal to shear strength reduction.

6. Loss of timber weight may reduce shear strength in soil immediately under the tree root systems. This action might result from "decompaction" of zones of soil earlier compacted by the weight of the tree.

7. Loss of root systems as a strength builder-maintainer in the soil mantle may be an important factor in accelerating flows after logging. This may reflect the destruction of inter-connected root systems by high-lead skid-roads. It may also reflect death and gradual deterioration of root systems after clear cutting. The time lag in slide activity after logging supports this view.

8. Debris in the bottoms of steep ravines aggravates stability conditions. Logs and stumps on side slopes contribute to such instability by rolling or sliding into the channel. The process follows a pattern--debris accumulates in the ravine bottoms and this is followed periodically by sweeping torrent-flows.

9. Slopes of 34° (67 percent) or more are highly susceptible to failure when conventional downhill high-lead logging is used.

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